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Message-Id: <200105221625.MAA19194@maia.usno.navy.mil>
Subject: status of IGU clock predictions
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Date: Tue, 22 May 2001 12:25:52 EDT
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In-Reply-To: from "robert.weber@aiub.unibe.ch" at Mar 05, 2001 9:37 am
X-Mailer: Elm [revision: 212.5]
Status: RO

Dear Colleagues,

Here are some items concerning the status of predicted satellite clocks in
the IGS Ultra-rapid combinations:

* ESU -- ESA is now including clock values in their IGU submissions and
  these are being included in the IGU clock combination.  ESA began
  submitting satellite clocks on 09 March 2001 for evaluation.  Thanks to
  Robert Weber, the ESA clocks began to be used in the IGU clock
  combination starting on 15 May.  This means that three centers now
  supply satellite clock predictions, which should improve the IGU clock
  reliability significantly.  I would like to thank the ESA group,
  especially Nacho Romero, for their efforts.

* Clock prediction strategies -- For the record, the appendix below gives
  an update of the clock prediction strategy used at USNO.  Some changes
  have been made since the description given in IGS Mail #2962.

* Current IGU clock performance -- For the 2001 EGS meeting I did an
  analysis of IGU clock predictions up to that time and found:

                            RMS clock           # solutions
                          residuals (ns)          editted
      IGU                      5.43                 33
      BRD                      7.13                  3
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which indicates only minimal improvement by the IGU (25%) with much poorer reliability than BRD.

* Use for real-time time dissemination -- As with other IGS clock products, the instability of the underlying timescale (linear alignment to BRD GPS time over 24-hr segments) is the greatest limitation (errors up ~20 ns level). An internal IGS timescale (work that is nearly finished by Ken Senior at USNO) should address this problem.

* Use for real-time remote synchronization -- Because synchronization between remote clocks is not sensitive to timescale errors, the IGU clock predictions can already be used for this purpose at the level of ~2 to ~3 ns globally (for known, fixed receiver locations).

* Use for real-time point positioning -- The current IGU products can be used for point positioning at the level ~1 m horizontal and ~2 m vertical versus ~2 m horizontal and ~3 m vertical for BRD. Predicted clocks are the dominant error for IGU, while clocks and orbits are both important for BRD.

* Future prospects -- Errors in IGU clock predictions grow roughly linearly with time (rather than as sqrt(t) expected for a random walk process) because the dominant errors are due to misfits of the clock model to the observed clocks and to jumps in the satellite frequencies. So it should be possible to improve the IGU clocks by shortening the update cycle from the current 12 hr. For example, changing from 12 hr (average latency of 9 hr) to 3-hr updates (average latency of 4.5 hr for the same 3-hr initial lag) would be expected to improve the IGU clocks by a factor of ~2. For wider acceptance, the reliabilty must be improved.

Best regards,
--Jim

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Appendix. Summary of USNO clock prediction strategy (update of IGS Mail #2962, 31 Jul 2000)
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The procedure used for our clock predictions is to extrapolate the estimated satellite clock values from the observational data preceding the prediction period. The observation period is nominally the 2 days immediately before the predictions. The 1st day before the predictions is alway used, and an earlier 24-hr solution using the same reference clock is sought. The search priority for a matching solution is: 1 day earlier, 1.5 day earlier, then 0.5 day earlier. If no matching solution is found after those attempts, then only the 1-day solution before the predictions is used.

Using all the data for each satellite clock individually, fits are made using the following models:

linear + sinusoid	for satellites with Cs clocks
quadratic + sinusoid	for satellites with Rb clocks

where the period of the sinuoid equals the orbital period (~12 hr). Some satellite clocks show very pronounced sinusoidal variations (most prominently PRN06) while most show little. The satellite clock types are maintained in a master file which is checked at runtime.

Continuity between the observed clocks and the predictions is enforced at the last epoch of the observation period. If the RMS of the fit to the observed clock of any satellite exceeds 10 ns (nominally over 2 days), then no clock predictions are reported for that satellite.

The USNO clocks are estimated relative to the clock state of a chosen tracking receiver (equipped with a H-maser external standard), which is not adjusted as the reference. Note that this reference procedure can cause occasional problems for both our observed and predicted clocks, for example when the chosen reference clock suffers a reset. In this case, no clock predictions will be issued. For this reason, it is vital for several analysis center to submit clocks for the IGU combination using different clock references.